AI-augmented SOL modelling for capturing impact of filaments on transport and PWI in mean field codes simulations

D. Zarzoso, Anna Glasser-Medvedeva
Aix-Marseille University, CNRS, Ecole Centrale, M2P2, UMR 7340 Marseille, France

Motivation, goal and outcomes of the project

Motivation

First wall erosion by particle blobs is one of the critical issues for the lifetime of plasma-facing components (PFC)

By spreading power across the field lines, these structures may potentially reduce concentrated heat loads at the divertor strike point

Predictive capability? A critical limitation to target fully predictive capability relies in the purely diffusive transport assumption that is made in the existing codes

Main goal

Detect blobs and filaments from experimental databases, and estimate their impact on turbulent transport using AI techniques

Outcomes

Filaments frequency, velocity, and correlation time will be extracted depending on the main plasma regimes in tokamak, sheath-limited, inertial and detached

Estimation of effective transport coefficients incorporating the ballistic features of turbulent transport

Database to be used

The experimental input of this study will be provided by ultra-fast swept reflectometry extensively used in the recent years in Tore Supra (West) and ASDEX Upgrade

Discharges from West (100) and ASDEX (3000)

Measuring density perturbations with a microsecond repetition rate along the radial line of sight on the tokamak's midplane with a high temporal resolution → characteristics of filaments, radial size and effective velocity

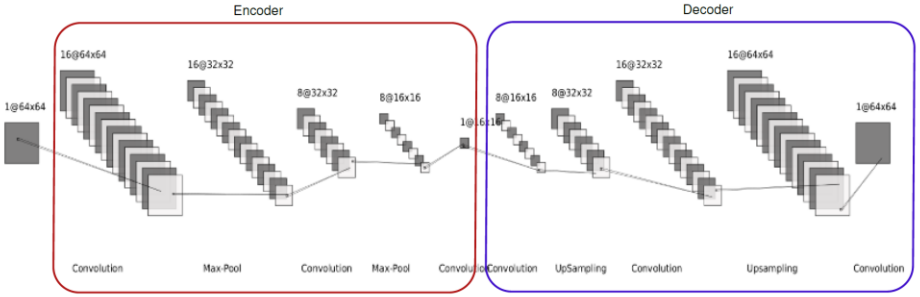
Experimental data confronted to outputs of the synthetic diagnostic FeDoT applied on fluid turbulence simulations (TOKAM + SOLEDGE3X) → hybrid database

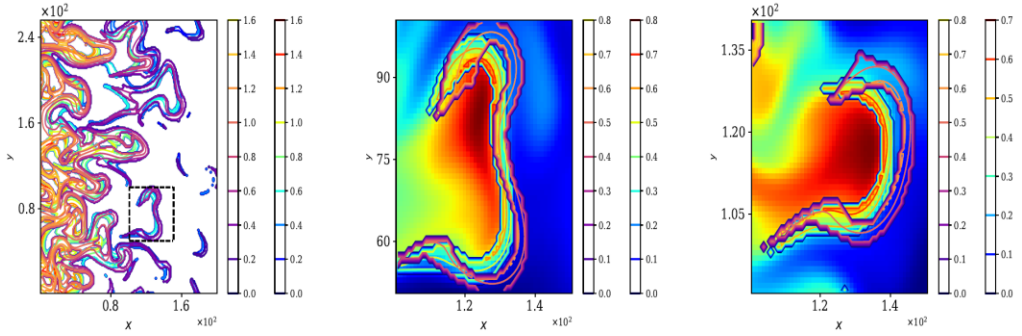
Artificial Intelligence algorithms to be developed

Automatic detection of 3D structures representing filaments and blobs using graph spectral clustering. The detection will be performed on 3D (or 2D for the case of TOKAM2D) time-evolving density fluctuations

- Including the time correlation/decorrelation of events
- Taking into account the physics at play

Dimensionality reduction will be applied to the reflectometer measurements using an auto-encoder combined with a standard multilayer perceptron (MLP), whose output will be the effective transport coefficient





Organisation of the project

Oct 2024 — Mar 2025 — May 2025 — Oct 2025 — Dec 2025

WP1
Optimizing data analysis and exploiting multi-machine database

- Task 1.1 Experimental database
- Task 1.2 Confrontation to numerical codes

WP2
AI detection of 3D and 2D turbulent structures

- T 2.1 **Automatic detection of 2D/3D structures**
- T 2.2 **AE + MLP to predict transport**

WP3
AI-augmented database for SOL ballistic transport model

- T3.1 **Identification of specific transport regimes observed in experiments**
- T3.2 **SOLEDGE simulations and comparison to existing numerical simulations**

4 deliverables in 2024 (D1 on experimental database, D2 and D3 on simulations and D4 on 2D/3D structure detection)
3 deliverables in 2025 (D5 on physics-informed detection, D6 on AI augmented database with transport coefficients, D7 AI tool to predict transport coefficient)
18-month postdoc involved in the project